

Effect of BMI, Body Fat Percentage and Fat Free Mass on Maximal Oxygen Consumption in Healthy Young Adults

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ABSTRACT

Introduction: Maximal oxygen consumption (VO_{2max}) is an important measure of cardiorespiratory capacity of an individual at a given degree of fitness and oxygen availability. Risk of cardiovascular diseases increases with increasing degree of obesity and a low level of VO_{2max} has been established as an independent risk factor for cardiovascular mortality.

Aim: To determine VO_{2max} in young adults and to find its correlation with Body Mass Index (BMI), Body Fat% and Fat Free Mass (FFM).

Materials and Methods: Fifty four (male=30, female=24) healthy young adults of age group 18-25 years after screening by Physical Activity Readiness Questionnaire (PAR-Q) participated in the study. Height was measured by stadiometer. Weight was measured by digital weighing scale with 0.1 kg sensitivity. Body fat% was measured by Bioelectrical Impedance Analysis (BIA)

method. FFM was calculated by subtracting fat mass from the body weight. VO_{2max} ($mL.kg^{-1}.min^{-1}$) was obtained by Submaximal Exercise Test (SET) by first two stages of Bruce Protocol with the basis of linear relationship between Heart Rate (HR) and oxygen consumption (VO_2). Data were analysed statistically in GraphPad Prism software version 6.01 for windows.

Results: VO_{2max} ($mL.kg^{-1}.min^{-1}$) of male (43.25 ± 7.25) was significantly ($p<0.001$) higher than female (31.65 ± 2.10). BMI showed weak negative correlation ($r= -0.3232$, $p=0.0171$) with VO_{2max} but Body Fat% showed strong negative correlation ($r= -0.7505$, $p<0.001$) with VO_{2max} . FFM positively correlated ($r=0.3727$, $p=0.0055$) with VO_{2max} .

Conclusion: Increased body fat is associated with decreased level of VO_{2max} in young adults. Obesity in terms of Fat% is a better parameter than BMI for prediction of low VO_{2max} .

Keywords: Aerobic capacity, Bruce protocol, Cardiorespiratory fitness, Obesity indices, Submaximal exercise test

INTRODUCTION

Maximal oxygen consumption (VO_{2max}) is the maximum amount of oxygen an individual can breathe in and utilize it to produce energy (ATP) aerobically [1]. There is a finite rate of oxygen transport from the lungs to the mitochondria to support oxidative production of ATP [2]. Determination of VO_{2max} is one of the most ubiquitous measurements in all of exercise science. It is one of the determinants of endurance performance which measures the cardiorespiratory capacity of an individual at a given degree of fitness and oxygen availability [3]. The direct measurement of VO_{2max} requires an extensive laboratory, specialized equipment, and considerable physical effort and motivation. These considerations increase the importance of submaximal exercise test to predict VO_{2max} from performance during walking or running or from heart rate (HR) during or immediately post-exercise [4]. Extrapolable HR to predict VO_{2max} is simple and valid [5]. This linear relationship of HR and VO_2 has been successfully employed in a number of fitness tests [6-10]. Treadmill exercise is highly desirable for determination of VO_{2max} in the laboratory because we can easily quantify and regulate exercise intensity. Hence, for determination of VO_{2max} , we used Bruce Protocol for submaximal treadmill exercise test based on HR- VO_2 relationship [4].

The worldwide prevalence of obesity has increased to more than double between 1980 and 2014 [11]. Risks of cardiovascular disease, hypertension, type II diabetes mellitus, osteoarthritis, gall bladder disease, and many types of cancer have increased with increasing degree of obesity. Low level of VO_{2max} has been established as an independent risk factor for cardiovascular mortality [12]. It is also considered as a casual risk factor for prediction of future hypertension [13]. BMI is a surrogate marker of body fat and is calculated from the weight and height of the subject [14]. But it

has a major limitation that it does not distinguish between body fat and FFM [15]. BIA is a validated indirect method for assessing the relative proportion of fat mass and FFM [16].

With this background, this study was aimed to determine the correlation of BMI, Fat% and FFM with VO_{2max} in young adults.

MATERIALS AND METHODS

A cross-sectional study was carried out in the Postgraduate Research Laboratory of Department of Physiology, MKCG Medical College, Odisha, India, from October 2015 to July 2016. Clearance from the Institutional Ethics Committee was obtained beforehand. Sample size of the study was calculated with reference of previous published research papers [17-19]. Formula used for sample size calculation was:

$$N = \{(Z\alpha + Z\beta)/C\}^2 + 3$$

Where N= Total number of subjects required

$Z\alpha/Z\beta$ = The standard normal deviate for α/β

$$C = 0.5 \times \ln\{(1+r)/(1-r)\}$$

r= expected correlation coefficient [20].

For this study, the expected correlation coefficient was $r=0.48$ with $\alpha=0.05$ and power of study 95%. Twenty percent extra subjects were included assuming a higher dropout rate. After taking written consent, 60 apparently healthy medical students in the age group of 18-25 years were taken as study population. All of them were asked to fill up the PAR-Q [21]. Three male subjects were excluded due to unfitness in screening by PAR-Q. One male and two females dropped out from the study due to their unwillingness for participation in exercise. The study group ($n=54$, male=30, female=24) were requested to fulfill the pre-test criteria for exercise and BIA test.

Pre-test Criteria [22]

1. Abstain from eating or drinking >4 hours
2. Abstain from strenuous exercise >24 hours
3. Abstain from caffeine, chocolate, alcohol and nicotine >48 hours
4. Void bladder completely within 30 minutes of test.

The test and assessment was carried out between 10.00 am to 12.00 pm to avoid circadian variation. An air-conditioned room temperature was set at 23°C. Anthropometric and body fat% measurements were taken in the laboratory in light clothing with adequate privacy. One female attendant was present during test of female subjects. Height was measured by stadiometer in centimeter to nearest 0.1 cm. Weight was measured by digital weighing scale with 0.1 kg sensitivity. Body fat% was measured by BIA method [23,24] using low current of 50 kHz, 500 μ A. FFM was calculated by subtracting fat mass from body weight {FFM= Body weight – (Body weight * Fat%)}. BMI was calculated by Quetelet's equation {BMI= Weight (kg)/Height (m)²}. Subjects were briefed about the aim of the exercise and a full demonstration of procedure was shown. They were familiarized with the instruments and trial was given before performing the actual test. The computerized treadmill (RMS Vega 201 Stress Test System) program was set according to the first two stages of the Bruce Treadmill Protocol [25] with a warm-up period of two minutes at gravitational level (0% grade) [Table/Fig-1]. Test termination criteria were followed according to ACSM's guidelines for exercise testing and prescription [26].

Stages	Time (min:sec)	Speed (mph)	Grade (%)
Warm up	2:00	1.7	0
Stage 1	3:00	1.7	10
Stage 2	3:00	2.5	12

[Table/Fig-1]: Stages for exercise on treadmill. Stage 1 and 2 are first two stages of Bruce Treadmill Protocol. {1% Grade = \tan^{-1} (1/100)^o angle}.

Test Termination Criteria

1. Onset of angina or angina like symptoms;
2. Decrease in systolic Blood Pressure (BP) of >10 mmHg from resting BP;
3. Excessive increase in BP (systolic >250 mmHg or diastolic >115 mmHg);
4. Failure of HR to increase with increased exercise intensity;
5. Shortness of breath or wheezing;
6. Leg cramps or claudication;
7. Nausea, light-headedness, confusion, ataxia, pallor, cyanosis, cold clammy skin;
8. If subject requests to stop

Steady state HR for each stage was recorded during the exercise. Continuous blood pressure was measured for checking appearance of any test termination criteria. VO_{2max} was calculated from the following formula [22].

Calculation

VO_{2max} was calculated as

$$VO_{2max} (\text{mL.kg}^{-1}.\text{min}^{-1}) = m (\text{HR}_{max} - \text{HR}_2) + VO_{2,2}$$

Where, $\text{HR}_{max} = 220 - \text{Age in years}$

$\text{HR}_2 = \text{Steady state heart rate for Stage 2}$

$VO_{2,2} = \text{Submaximal predicted } VO_2 \text{ for Stage 2}$

$m = \text{Slope of the HR and } VO_2 = (VO_{2,2} - VO_{2,1}) / (\text{HR}_2 - \text{HR}_1)$

VO_2 for any stage was calculated as:

$$VO_2 (\text{mL.kg}^{-1}.\text{min}^{-1}) = \{(\text{Speed in m.min}^{-1}) \times 0.1\} + \{(\text{Speed in m.min}^{-1}) \times 1.8 \times \text{Grade in decimal}\} + 3.5$$

Speed conversion: 1 mph = 26.8 m.min⁻¹

STATISTICAL ANALYSIS

Data obtained were stored for statistical analysis. For Pearson correlation, we set α (two-sided) = 0.05 and Power of study = 95%. Unpaired t-test, Pearson correlation and linear regression analysis were done in GraphPad Prism 6 for Windows (Version 6.01, 2012) and in Microsoft Excel® 2010 for Windows.

RESULTS

Mean age of subjects (n=54) was 20.09±2.92 years. Mean VO_{2max} (mL.kg⁻¹.min⁻¹) of male was 43.25±7.25 and female was 31.65±2.10. The difference was statistically significant (p <0.001) [Table/Fig-2].

Variable	Male (n=30)	Female (n=24)	t-test p-value*
VO_{2max} (mL.kg ⁻¹ .min ⁻¹)	43.25±7.25	31.65±2.10	<0.001

[Table/Fig-2]: VO_{2max} of male and female subjects. *Unpaired t-test with 95% confidence interval, two tail p-value <0.05 was considered statistically significant.

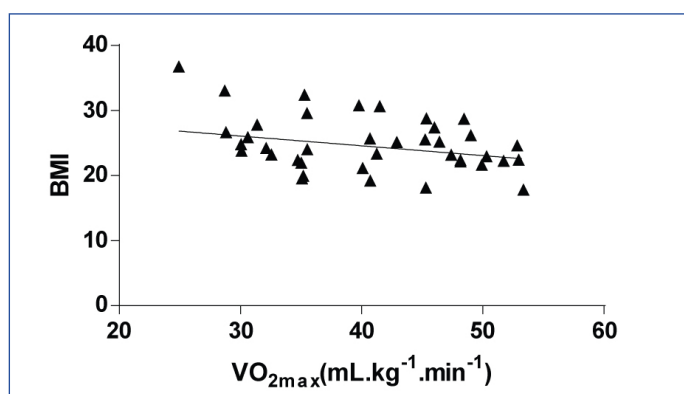
Mean BMI of male subjects was 25.14±4.61 which was in 'pre-obese' category. BMI of female subjects was 24.53±2.27 which was in 'normal' range according to WHO BMI criteria [27]. Fat% of female subjects was higher (32.89±3.06) than male subjects (23.65±5.55) and the difference was statistically significant (p<0.001). Fat% of female was in unhealthy (too high) range of body fat% (i.e., more than 32%) and that of male was in acceptable range (higher end) of body fat% (i.e., 16-24%) according to Lohman categorization [5,28]. FFM of male subjects (54.55±9.11) kg was higher than female subjects (41.71±4.52) kg. Unpaired t-test was done to compare these three parameters between male and female and the result is shown in [Table/Fig-3].

Parameters	Male (Mean±SD)	Female (Mean±SD)	t-test, p-value*
BMI (kg/m ²)	25.14±4.61	24.53±2.27	0.5553
Fat%	23.65±5.55	32.89±3.06	<0.001
FFM (kg)	54.55±9.11	41.71±4.52	<0.001

[Table/Fig-3]: Comparison of BMI, fat% and FFM between male and female subjects. *Unpaired t-test with 95% confidence interval, two tail p value <0.05 was considered statistically significant.

While doing correlation study, it showed that BMI has a negative correlation ($r = -0.3232$, $p = 0.0171$) with VO_{2max} .

[Table/Fig-4] shows the linear regression graph between BMI and VO_{2max} . Fat% had a strong negative correlation ($r = -0.7505$, $p < 0.0001$) with VO_{2max} . The linear regression graph between Fat% and VO_{2max}

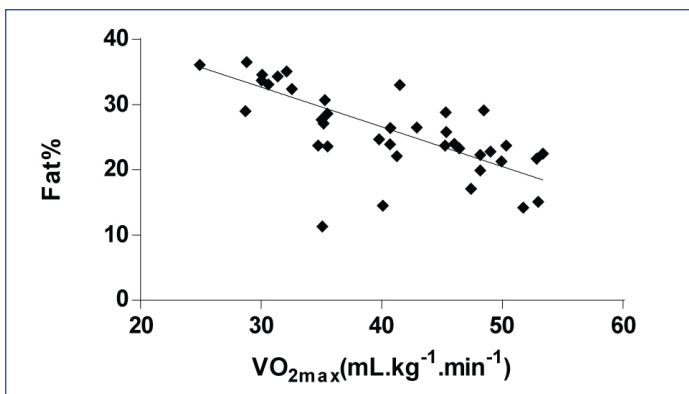


[Table/Fig-4]: Relationship between BMI and VO_{2max} . ($R^2 = 0.1045$, $F = 6.065$, $p = 0.0171$, Equation: $Y = -0.1502 \times X + 30.59$).

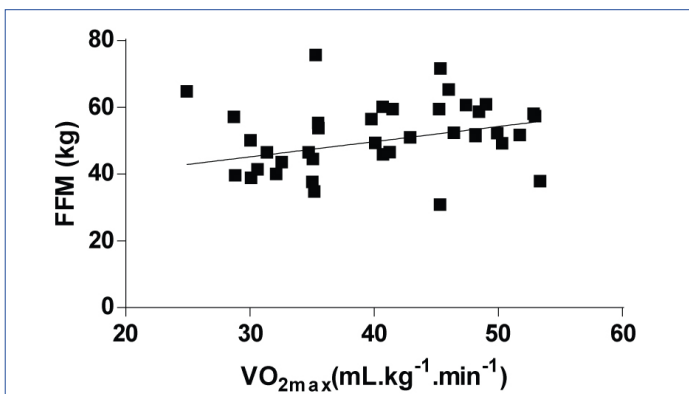
is shown in [Table/Fig-5]. FFM was positively correlated ($r = 0.3727$, $p = 0.0055$) with VO_{2max} which is presented as linear regression graph with trend line in [Table/Fig-6].

DISCUSSION

VO_{2max} is one of the best measures of fitness for exercise. However, measuring VO_{2max} is not only intended to predict fitness for exercise,



[Table/Fig-5]: Relationship between fat% and VO_{2max} ($R^2 = 0.5633$, $F = 67.08$, $p = <0.001$, Equation: $Y = -0.6090 \cdot X + 50.96$).



[Table/Fig-6]: Relationship between FFM and VO_{2max} ($R^2 = 0.1389$, $F = 8.390$, $p = 0.0055$, Equation: $Y = 0.4542 \cdot X + 31.54$).

it also helps in identifying future health risks associated with low VO_{2max} . The subjects participated in this study lead a sedentary life style and none of them were exercising. There is no normative values for categorization of level of VO_{2max} , but according to the percentile value by Cooper Institute, the mean VO_{2max} (ml.kg-1.min-1) of male (43.25 ± 7.25) was in 'fair' and female (31.65 ± 2.10) was in 'poor' category [26]. According to the WHO BMI category, females were in 'normal range' of BMI and their aerobic capacity was less than male subjects who were in 'pre-obese' category according to BMI. This difference may be due to different type of distribution of fat and FFM in male and female. Though the result indicated a negative correlation ($r = -0.32$) between BMI and VO_{2max} , the R^2 value (0.10) suggest it to be a weak correlation. Shetty P et al., Laxmi CC et al., Sterkowicz S et al., Hsieh PL et al., also found a negative correlation between BMI and VO_{2max} [17,18,29,30].

Male and female both had higher than average fat% according to Lohman categorization [5,28]. Both of them also had fat% more than of 'fitness' level of body fat% if we consider the American Council on Exercise categorization [31]. Lack of exercise or sedentary lifestyle of the subjects may be the cause of this increased level of fat%. Result of this study showed strong negative correlation between fat% ($r = -0.75$) and VO_{2max} . Hence, a young adult person with increased body fat% would have less aerobic capacity compared with a person with low body fat%. This finding supports the study of Minasian V et al., Watanabe K et al., Amani AR et al., Sharma VK et al., and Ostogic SM et al., [19,32-35]. Though the age of the subjects of these studies was different than our study, but the negative effect of increased body fat on VO_{2max} is evident.

Sedentary life style or inadequate physical activity is not only associated with increase in body fat%, it is also a cause of decrease in relative muscle mass. More the muscle mass involved in exercise, greater the contribution of muscle pump to venous return. Hence, increase in muscle mass help to receive an increased cardiac output. In this study, we found a positive correlation ($r = 0.3727$) between the FFM and VO_{2max} . Though this is not a strong correlation, but the positive correlation coefficient indicates that increase in FFM

may be responsible for increased VO_{2max} . This result supports the finding of the study by Morinder G et al., who found the correlation coefficient almost similar to this study [36]. Studies by Goran M et al., and Vsetulova E et al., also found positive correlation between the VO_{2max} and FFM but with different correlation coefficient values [37,38].

There was higher correlation coefficient of fat% and VO_{2max} compared to that of BMI and VO_{2max} . This finding indicates obesity in terms of fat% is a better parameter than BMI for prediction of low cardiorespiratory functional status of young adults. Therefore, during exercise prescription, if feasible, measurement of total body fat% is more acceptable parameter than BMI. Increase in regular physical activity or exercise may help decrease in body fat% which may help in relative increase in FFM and increase in VO_{2max} . The beneficial effect of exercise on increment of VO_{2max} has been established in study by Shete AN et al., Hence, a suggestion to reduce body fat% by the help of increased physical activity or exercise would help to decrease health risks in young adults [39].

LIMITATION

In this study, we took only healthy young adult students of age group 18-25 years. A study with different age groups with wide range of BMI and fat% may provide a better scenario of relation between the obesity and aerobic capacity in general population. Determination of VO_{2max} with submaximal treadmill exercise test based on HR- VO_2 relationship though validated and widely used is not a gold standard test.

CONCLUSION

Increased body fat% is associated with decreased level of VO_{2max} and increase in FFM helps in increasing the VO_{2max} in healthy young adults. Obesity in terms of fat% is a better determinant than BMI for a low VO_{2max} .

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